

Citation for published version:

Blondel, P & Hatta, A 2017, 'Acoustic Soundscapes and Biodiversity - Comparing Metrics, Seasons and Depths with Data from the NEPTUNE Ocean Observatory offshore British Columbia', Paper presented at Underwater Acoustics Conference and Exhibition, Skiathos, Greece, 3/09/17 - 8/09/17 pp. 763-768.

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

[Link to publication](#)

University of Bath

Alternative formats

If you require this document in an alternative format, please contact:
openaccess@bath.ac.uk

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

ACOUSTIC SOUNDSCAPES AND BIODIVERSITY – COMPARING METRICS, SEASONS AND DEPTHS WITH DATA FROM THE NEPTUNE OCEAN OBSERVATORY OFFSHORE BRITISH COLUMBIA

Philippe Blondel ^a, Arief Ahmad Zailani Hatta ^a

^a Department of Physics, University of Bath, United Kingdom

Philippe Blondel, Department of Physics, University of Bath, Claverton Down, Bath BA2 7AY, UK; P.Blondel@bath.ac.uk

Abstract: *Acoustic soundscapes are made of the complex interplay of weather processes (rain, wind, and sea states), animal noises (from fish to marine mammals) and acoustic signatures of anthropogenic activities (from shipping to mapping/prospection and other offshore actions). There is mounting concern about the effects of increases in shipping and variations induced by climate change on the biodiversity in the oceans, and this will be investigated using large-scale and long-term measurements acquired by Ocean Networks Canada. NEPTUNE is the largest cabled ocean observatory and it has been gathering data since 2007, across several nodes offshore British Columbia. Broadband, high-fidelity measurements of sound are accessible across a range of environments and depths, from the coast of Vancouver Island to canyons and abyssal plains. Selected datasets are processed with the standard PAMGuide Matlab/R package (Merchant et al., 2015) and associated to weather, shipping and other acoustic processes. Acoustic diversity indices are computed with the Seewave R package (Sueur et al., 2016), originally developed for terrestrial acoustics but increasingly used in marine environments. We compare the variations of standard acoustic metrics (broadband SPL and frequency-dependent values) with acoustic biodiversity measurements, investigating the effects of integration times, frequency ranges, depths and seasonal variability.*

Keywords: *ambient noise, seafloor observatories, NEPTUNE, ecoacoustics, biodiversity.*

1. OCEAN OBSERVATORIES AND LONG-TERM DATASETS

Advances in instrumentation and subsea engineering have led since the 1990s to a growing series of ocean observatories, providing real-time access to a variety of measurements of the oceans, their geology and their ecology [1]. A leading example is the *NE Pacific Time-series Underwater Network Experiments* (NEPTUNE) observatory is located offshore Vancouver Island, British Columbia (Canada) and operated by Ocean Networks Canada (ONC). The extensive subsea infrastructure includes close to 1,000 km of fibre optic cables providing access to a range of instruments at different depths (Fig. 1). These cover the continental shelf at Folger Passage (ca. 10 km from shore, 20–100 m deep), the continental slope at Barkley Canyon (400–985 m), Clayoquot Slope (1,250 m), the Endeavour segment of the Juan de Fuca Ridge (2,200–2,400 m) and abyssal plains in the Cascadia Basin (2,660 m). Measurements available on line (<http://www.oceannetworks.ca/DATA-TOOLS>) include ambient noise at many of these locations. Additional information, for example about fish species or environmental parameters at specific times, is also available through ONC (see [2] for more details).

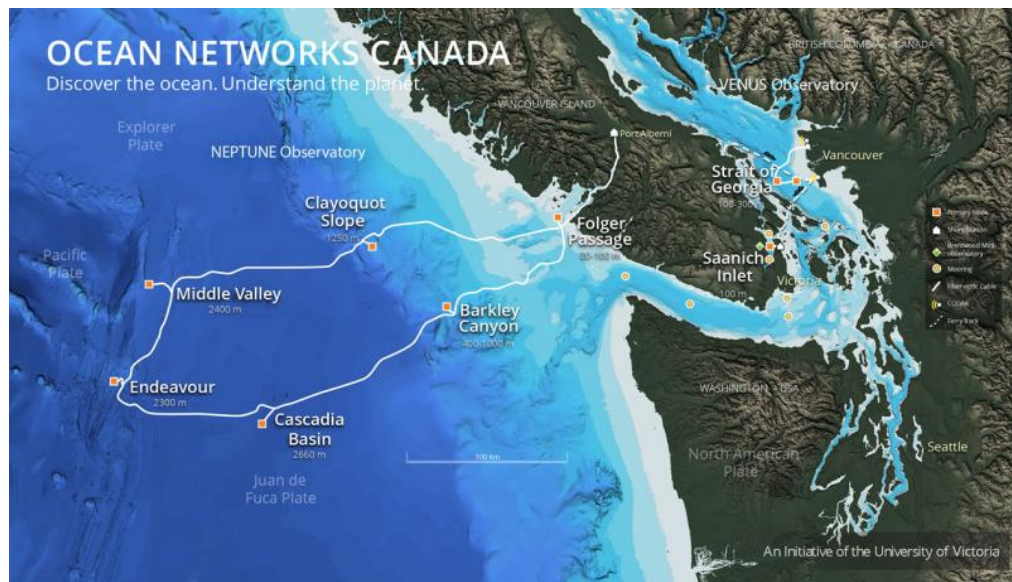


Fig.1: Generic setup of the NEPTUNE observatory operated by Ocean Networks Canada. Image source: <https://www.oceannetworks.ca/about-ocean-networks-canada>.

NEPTUNE started data collection in December 2009, and with close to 8 years of continuous measurements, it provides a rich background to long-term studies of how the NE Pacific evolves with changes in climate and human activities. Traditional analyses of sound files, looking at individual spectrograms and identifying each individual contribution, are not possible due to the sheer size of available data (8 years with 96 kHz sampling rate, in the case of ambient noise, yields in excess of 20 TB of raw data for each of the many hydrophones). Depending on the studies, it might be necessary to detect short (< 1 second) transients at the same time as long (> 1 month) trends. Data quality will vary with the ageing of components in the challenging deep-sea environments, part changes in the acquisition chain, and potential interference from neighbouring instruments (Fig. 2). Processing should therefore be robust, to account for these variations, and multi-scale, to detect all processes of interest.

2. STANDARD METRICS AND ECO-ACOUSTICS

Standard metrics describe sound levels and their statistical variations over different bandwidths and timescales [3-5]. The open-source *PAMGuide* Matlab/R package [5] is increasingly used across the field of Passive Acoustic Monitoring, underwater and in air. It is used here on a selection of sound files corresponding to the 2009/2010 winter season and spring 2010, centred for a full tidal cycle around the solstice and equinox respectively. Fig. 2 shows a typical spectrogram, for a single file close to 1 minute long. The full bandwidth is used, with 10-ms windows, Hann filtering and 50% overlaps, accounting for the full specifications of the data acquisition chain. The generally quiet background is affected by strong and continuous levels below 150 Hz, and marred by regular pings from a neighbouring ADCP. Short and regularly spaced, they produce varying echoes and harmonics, clearly visible in this segment. In some occasions, these pings overlap with other phenomena of interest, therefore filtering out their respective time intervals or frequency bands is not a viable option when looking over long times.

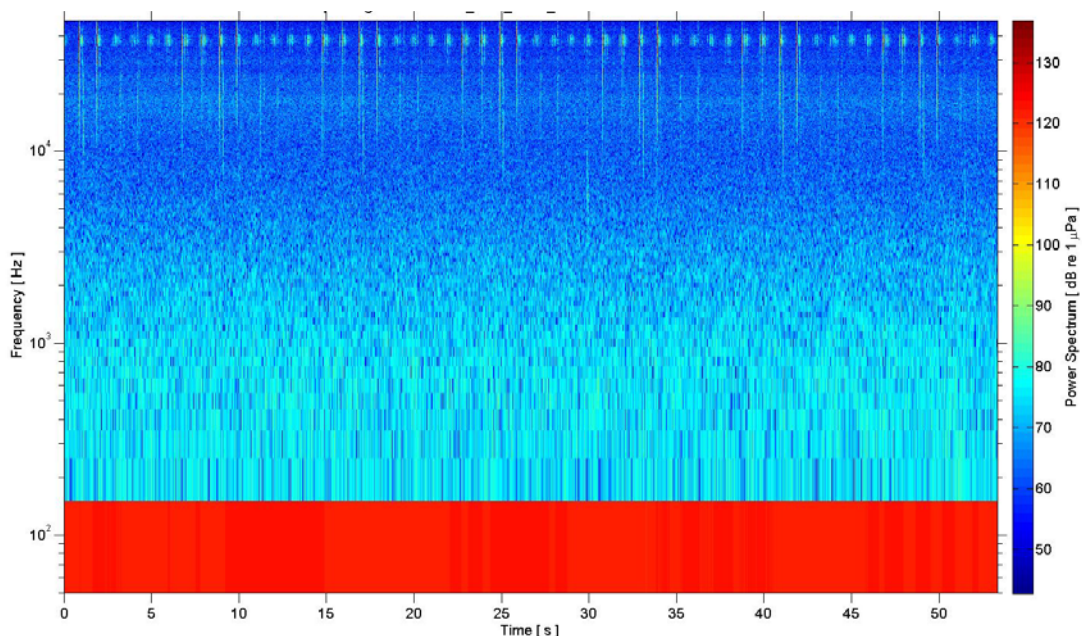


Fig.2: Typical spectrogram of ambient noise measured at the Folger Passage observatory (in this case on 1st January 2010, close to midnight), processed with PAMGuide [5]. See text for details.

Different metrics expected to quantify acoustic diversity are computed with the *Seewave* R package [6], originally developed for terrestrial acoustics but increasingly used in marine environments. Publications do not always present the processing choices (e.g. frequency or time resolution), sometimes using the values as “magic bullets” quantifying local variations over short periods (e.g. a few days). Because there will likely be differences between the types of data (sampling rates, duty cycles, etc.) and ecosystems surveyed, this study is focusing on a few indices.

The Acoustic Complexity Index (ACI), developed by [7], is based on the assumption that biotic sounds have an intrinsic variability of intensities, whereas anthropogenic

sounds have more constant values ([7] note that impulsive sounds like car horns will affect ACI values, and the same should be true underwater, e.g. with sonar pings). Preliminary studies [8] in coastal reefs offshore New Zealand indicated strong variations with dawn and dusk. Similar indices have been used successfully in Australia [9], and Harris (*methods.blog* post, unpublished, 2016) indicated it was a good indicator of species evenness. Here, the ACI is computed for a full month with the default 512-sample window (5.3 ms, i.e. including enough samples in the times between pings). The time intervals over which ACI is calculated are most often unreported. Our comparing of intervals systematically varying from 1 minute to 1 hour reveals no difference in averaged ACI values, but decreases in their relative standard deviations as the integration time increases. Times of 1 minute are used to measure near-instantaneous variations, and values averaged over 1 hour are presented over the full tidal cycle corresponding to the 2009 winter solstice (Fig. 3).

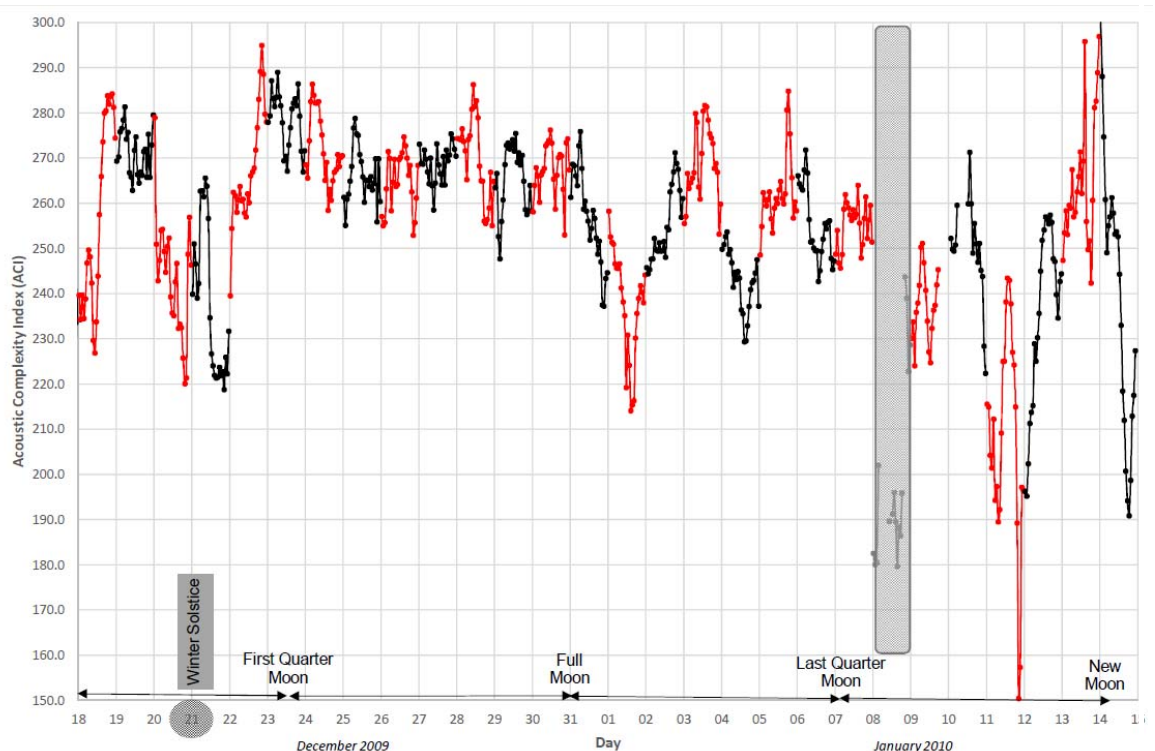


Fig.3: Variations of the Acoustic Complexity Index over a full tidal cycle corresponding to the 2009 winter solstice. Alternative days are highlighted in red and black respectively. Time is GMT (8 hours ahead of local time). A day of potentially anomalous data is shaded in grey and the lunar cycle shows other scales of variations.

ACI values are generally higher and spanning a broader range (200 – 280) than in [8] (values of 130 – 160). This might be due to the longer timescale over which it was measured (a month compared to a few days) and the difference in environments (coastal temperate vs. reef). Fig. 3 shows strong diurnal variations, with dawn and dusk patterns. These are more visible when looking at intra-hour variability (Fig. 4), calculated by looking at standard variations of ACI values computed for every minute during each hour, when daily peaks occur mostly at dawn, and often (but with lesser values) at dusk.

The monitoring of ACI values over a suitably long timescale, corresponding in this case to a full tidal cycle, also shows systematic decreases during the New Moons (December 2009 and January 2010 in this case). ACI generally picks up as the Moon

moves to its next quarter, and then drops for half a day afterwards. Detailed analyses of the spectrograms for each hour is expected to identify the frequency bands contributing most to this complexity, and the relevant physical, biological or anthropogenic processes (e.g. increased shipping at particular times). Comparison with weather information will help refine these interpretations.

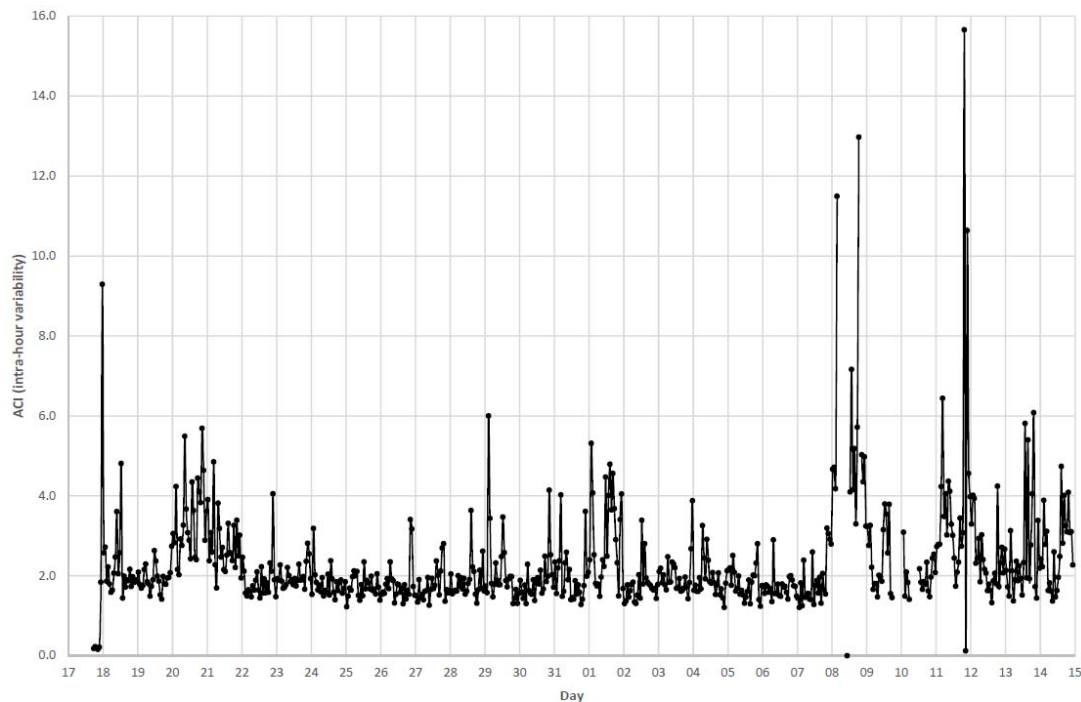


Fig.4: Intra-hour variability of the Acoustic Complexity Index, for the same full tidal cycle as Fig. 3, calculated for 1-minute intervals within each hour.

Harris (unpublished, 2016) summarised the attributes of relevant eco-acoustic metrics as: (1) matching species diversity; (2) being robust to changes in spectral resolutions, to compare different surveys and reduce data storage requirements; (3) being resistant to natural interference (mainly wind) and to anthropogenic noise. Figs. 3-4 show a first analysis of a very large dataset (28 days x 24 hours x 96,000 samples/second = $0.232 \cdot 10^{12}$ measurements), and on-going analyses are now trying to unravel the different contributors to Acoustic Complexity and ACI values calculated with the approach of [7]. These analyses will also investigate changes with spectral resolutions and with duty cycles.

Additional eco-acoustic indices (not presented here) include Acoustic Diversity Indices (ADI [6]) and similar parameters. ADI was similarly computed over different scales, but showed little intra-day variations on the periods it was tested on. Other values, like the Normalised Difference Soundscape Index, show promise but require thorough filtering of the different sound files to remove the most obvious artefacts or constant frequency bands (e.g. Fig. 2). They are now compared with systematic variations of Sound Pressure Levels (SPLs) over similar timescales. These results are also compared over several seasons.

3. CONCLUSIONS

Eco-acoustic indices are sometimes presented as “golden bullets” enabling easy quantification of biodiversity in complex datasets, but their translation from aerial acoustics to underwater acoustics needs to be informed by quantitative descriptions of

differences between environments and the choice of processing parameters. They also need to be related to established metrics, like frequency bands and SPLs. The first steps of this study have used large datasets acquired by Ocean Networks Canada, with high quality hydrophones sampling continuously at very high rates for very long periods (years). Some eco-acoustic indices, like the ADI, do not seem to have much relevance underwater, at least in this environment and at the season presented. Other eco-acoustic indices, like the ACI, conversely show systematic variations related to physical and biological processes.

4. ACKNOWLEDGEMENTS

This study would not have been made possible without the dedication and openness of Ocean Networks Canada and staff at the NEPTUNE Ocean Observatory, who tirelessly share their hard-won measurements with the entire scientific community. AAZH contributed to this study as part of the first cohort of PhURST (Physics Undergraduate Research Student Training) in 2016/17.

REFERENCES

- [1] **Favali, P., L. Beranzoli, A. De Santis**, *Seafloor Observatories – A new vision of the Earth from the Abyss*, Springer-Praxis, 676 pp., 2015.
- [2] **Barnes, C.R., M.M.R. Best, F.R. Johnson, B. Pirenne**, NEPTUNE Canada: Installation and initial operation of the world's first regional cabled observatory, p. 415-438, in Favali, P., L. Beranzoli, A. De Santis (eds.), "Seafloor Observatories – A new vision of the Earth from the Abyss", Springer-Praxis: Chichester, 2015.
- [3] **Robinson, S.P., P.A. Lepper, R.A. Hazelwood**, *Good Practice Guide for Underwater Noise Measurement*, NPL Good Practice Guide No. 133. National Physical Laboratory, UK, 2014.
- [4] **Merchant, N.D., K.M. Fristrup, M.P. Johnson, P.L. Tyack, M.J. Witt, Ph. Blondel, S.E. Parks**, Measuring acoustic habitats, *Methods in Ecology and Evolution*, 6 (3), pp. 1-9, 2015.
- [5] **Merchant, N.D., Ph. Blondel, D.T. Dakin, J. Dorocicz**, Averaging underwater noise levels for environmental assessment of shipping, *J. Acoust. Soc. Am.*, 132(4), pp. EL343-EL349, 2012.
- [6] **Sueur, J., T. Aubin, C. Simonis**, Seewave: a free modular tool for sound analysis and synthesis, *Bioacoustics*, 18, pp. 213-226, 2008.
- [7] **Pieretti, N. A. Farina, D. Morri**, A new methodology to infer the singing activity of an avian community: The Acoustic Complexity Index (ACI), *Ecol. Ind.*, 11, pp. 868-873, 2011.
- [8] **Harris, S.A., C.A. Radford**, Marine Soundscape Ecology, In *Inter-noise 2014*, 9 pp., 2014.
- [9] **McPherson, C., B. Martin, J. MacDonnell, C. Whitt**, Examining the value of the Acoustic Variability Index in the characterisation of Australian marine soundscapes, *Proc. Acoustics-2016*, 2016.